

Review of Recent Studies from Central and Eastern Europe Associating Respiratory Health Effects with High Levels of Exposure to "Traditional" Air Pollutants

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The serious environmental problems caused by decades of Communist mismanagement of natural resources in countries of Central and Eastern Europe have been brought to light in recent years. All environmental media, including air, water, food, and soil have been burdened with toxic chemicals. Large segments of the population have been, and are now being exposed to air pollution levels exceeding guidelines established by western countries and by international health organizations. This review focuses on epidemiologic evidence regarding health effects of poor air quality in Central and Eastern Europe. It appears that short-term high levels of air pollutants (primarily particulates and SO_2) may increase mortality in sensitive parts of the population. Associations were also seen between air pollution levels and prevalence of respiratory diseases as well as lung function disturbances in adults and children. One study indicated that urban air pollution increased the risk of lung cancer. Several investigations pointed to strong interactions between risk factors. The poor scientific standard of the studies often makes it difficult to evaluate the findings. Several steps should be taken to develop environmental epidemiology in Central and Eastern Europe, including international collaboration in research projects and training. — *Environ Health Perspect* 103(Suppl 2):15–21 (1995)

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Introduction

The environment in Central and Eastern Europe has experienced extreme degradation over the past four decades. For example, the former East Germany annually produced between 5 and 6 tons of sulfur dioxide per km^2 . While urban air pollution declined steadily in Western Europe over the last decades, the situation hardly improved in Central and Eastern Europe. Sulfur dioxide emissions deposited in Czechoslovakia increased from 0.9 million tons in 1950 to 3.5 million tons in 1985. In industrial areas and in cities, SO_2 deposition reached extremely high levels: 120 tons/ km^2 in Northern Bohemia; 77 tons/ km^2 in Prague. Average annual levels of particulates significantly exceeded the highest admissible concentration limits; for example, in Prague 199 $\mu\text{g}/\text{m}^3$ and in Silesian Ostrava 152 $\mu\text{g}/\text{m}^3$.

Power generation systems are the main sources of air pollution emissions as well as heat production for the industrial and municipal sectors. These sources are responsible for about 90% of SO_2 emissions and about 60 to 70% of emissions of dust and nitrogen oxides. Motor vehicles are another significant source of air pollution, being responsible for about 25% of nitrogen oxide emissions.

Poland, the former Czechoslovakia, and East Germany are among those countries in Europe where the emission of pollutants into the air is the greatest. It is widely recognized that environmental conditions are most appalling in the heavily industrialized "Dirty Triangle" region of Northern Bohemia, Silesia, and adjacent portions of eastern Germany where smog episodes often occur. This region frequently experiences peak ambient SO_2 concentrations of more than 300 $\mu\text{g}/\text{m}^3$ and annual average values of more than 60 $\mu\text{g}/\text{m}^3$. In addition, many of these areas have high ambient concentrations of acid aerosols (mainly sulfates).

In the review of papers, some evaluation criteria have been set up for the assessment of the scientific evidence provided by the studies under consideration. The evaluation criteria were based on the design of the study, quality of air pollution measurements (concentration/dose), methods of

health assessments, exposure–response data, accounting for confounders, and size of the study groups.

Mortality and Hospital Morbidity Studies

Epidemiologic studies concerning acute effects of air pollution on health have been carried out in areas fraught with a potential smog hazard. Bredel and Herbarth (1) and Herbarth (2,3) from East Germany published investigations on acute effects of air pollution over a period of 6 and 8 years, respectively. A significant correlation was found between air pollution measured by SO_2 and specific morbidity recorded by emergency calls. The relationship between cases of illness of the respiratory tract, especially among children, and unfavorable air pollution was particularly marked. During smog situations concentrations of sulphur dioxide of more than 4.5 mg/m^3 (30-min average) or 2.5 mg/m^3 (24-hr average) were observed. The findings were confirmed by an investigation carried out in another heavily polluted city (Halle), in which the same methods of analysis were applied. An increase in the number of emergency calls due to illnesses of the respiratory tract was observed in adults at 0.8 $\text{mg SO}_2/\text{m}^3$ and in children at 0.24 $\text{mg SO}_2/\text{m}^3$.

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SO₂/m³ (daily averages). The respiratory effects usually appeared with a time delay of 24 hr.

To evaluate the relationship between atmospheric air pollution and mortality, a longitudinal daily mortality study was carried out by Krzyzanowski et al. (4) in Cracow (Poland) over the period 1977 to 1989. The analysis was restricted to winter months. In 1167 winter days with data on air pollution, on average 18.4 deaths of Cracow residents occurred daily. PM₂₀ concentrations exceeded 300 µg/m³ in 21%, and SO₂ exceeded 200 µg/m³ in 19% of the days. The correlation coefficients of daily number of deaths with air pollution in 24 hr preceding the day of death were 0.093 ($p < 0.01$) for PM₂₀, and 0.141 ($p < 0.001$) for SO₂. Similar correlations were found for air pollution levels in 4 days preceding death, and the correlation decreased for earlier days. The effects were more pronounced in people over 65 years of age than in the younger age category, especially in males. After adjustment for SO₂ levels, PM₂₀ had no additional effect on mortality. It was estimated that the daily number of deaths due to respiratory system diseases increased by 19%, with an increase of SO₂ concentrations of 100 µg/m³, and deaths due to circulatory system disease by 10% (Tables 1,2).

Lautenschlager et al. (5) investigated a relationship between mortality and smog in East Berlin from 1986 to 1991. A significant increase in mortality was observed in persons older than 75 years when daily averages of SO₂ were higher than 1 mg/m³ and the concentration lasted longer than three days.

Prevalence Studies of Respiratory Diseases in Adults

A number of epidemiologic studies over the last 10 years have been carried out on air pollution and chronic respiratory diseases. Chronic nonspecific respiratory diseases have been studied by Pudelski (6) in the heavily polluted industrial town Zabrze in Upper Silesia. Based on a cross-sectional study of the adult inhabitants (age range 20–64), the prevalence of chronic bronchitis was found to be 28.5% in men and 9.7% in women. A reduction in ventilatory function (FEV₁% < 60%) was found in 2.1% of the males and 1% of the females. The highest incidence of chronic bronchitis was seen in smoking men employed in jobs with high air pollution levels. Men with permanent residence

in the highly polluted area of the city had a significantly higher incidence of chronic bronchitis, and it was even more pronounced in those who were smokers. However, there was no clear association of respiratory disorders with the gradient of air pollution within the study area. The analysis of differences between men and women was not adjusted for smoking or occupational exposure.

A case series study was performed by Rogala et al. (7) in Upper Silesia to examine the effect of air pollution among inhabitants of two towns with different degrees of pollution on the prevalence and clinical course of bronchial asthma. Classification of air pollution was based on dust fallout (sedimentation rates in tons per km² and year), average annual concentration of SO₂, average concentration of SO₂ during the heating season, and NO_x recalculated to N₂O₅ level. The data on health status were collected by questionnaires distributed in both towns and by examining the

clinical records of selected patients with bronchial asthma. The study did not show a significant correlation between air pollution and prevalence of bronchial asthma. It did confirm that in the region most of the patients have the atopic form of bronchial asthma, with a prevalence around 1%. The authors documented more severe ventilation disorders in asthmatic patients in the town with higher air pollution levels. The most prominent changes were seen in maximal midexpiratory flow rate (MMFR) and one-second forced expiratory volume (FEV₁).

The correlation between asthma, chronic bronchitis, and air pollution in the area of residence was analyzed by May (8) over 3 years (1979–1982) in Polish military conscripts. A clear gradient of respiratory diseases was found with SO₂ concentrations as well as a high correlation of rates of chronic bronchitis and asthma with air pollution levels. Since the diagnostic criteria were based only on

Table 1. Correlation coefficients of daily number of deaths and air pollution levels.

Lag, days	SO ₂		PM ₂₀	
	Adjusted	Crude	Adjusted	Crude
0	0.141**	0.079*	0.092*	0.005
1	0.136**	0.074*	0.088*	0.000
2	0.162**	0.097*	0.119**	0.028
3	0.146**	0.081*	0.094*	0.004
4	0.099**	0.037	0.071	-0.018
5	0.115**	0.046	0.042	-0.047
6	0.093*	0.027	0.017	-0.070
7	0.077*	0.010	0.028	-0.060
Mean 0–3	0.179**	0.102**	0.121**	-0.016
Mean 0–7	0.171**	0.083*	0.103**	-0.013

** $p < 0.001$; * $0.001 < p < 0.01$ (two-sided test). From Krzyzanowski et al. (4).

Table 2. Linear regression models of daily number of deaths due to specified causes.

		Regression model including ^a		
		Only SO ₂	Only PM ₂₀	SO ₂ and PM ₂₀
All except injury	SO ₂	b	—	1.66**
		SE(b)		(0.37)
	PM ₂₀	b	0.49*	-0.11
		SE(b)	(0.13)	(0.18)
Circulatory system diseases	SO ₂	b	—	1.14**
		SE(b)		(0.27)
	PM ₂₀	b	0.26*	0.16
		SE(b)	(0.09)	(0.13)
Respiratory system diseases	SO ₂	b	—	0.18
		SE(b)		(0.08)
	PM ₂₀	b	0.05	-0.12
		SE(b)	(0.03)	(0.39)

^aOther factors in the models: years, months, Sundays. ^bEstimated change in number of deaths per 100 µg/m³ of pollutant (mean in 4 days, lag 0–4); SE(b), standard error of b. Significance of $b = 0$: ** $p < 0.001$; * $0.001 < p < 0.01$. From Krzyzanowski et al. (4).

symptoms, a possible reporting bias makes it difficult to interpret the results.

An analysis of the association between number of daily visits to a general practitioner and air pollution (SO_2 , SPM, NO_2 , and fluorides) was carried out in Cracow by Seroka et al. (9). The daily number of visits, and specifically those due to respiratory diseases, was significantly related to SO_2 concentrations. High concentrations of suspended particulate matter (SPM) were associated with a greater number of visits due to diseases of the cardiovascular system, but only on warm days. Some association was also found between both NO_2 and fluorides and number of visits. The authors did not adjust for other air pollutants when analyzing the effect of one factor.

Kleine (10) from East Germany demonstrated that there are spatial differences in the prevalence in some of diseases of the respiratory tract in territories differing in air pollution. The data came from a questionnaire survey of children born in the regions of Bitterfeld and Wismar in 1982. Bronchitis, pseudocroup, and chronic cough were significantly more common in the children from Bitterfeld (three times more frequent than in Wismar).

In a study by Bretter et al. (11) in 19 urban localities from Transylvania in Rumania, the air quality and health status of the population was monitored over a 6-year period (1983–1989). A significant correlation was indicated between air pollution level and disease incidence. In adults a significant correlation was observed between malignant tumors of the respiratory tract and sulfur dioxide and chromium; in children there was a significant correlation between SO_2 and bronchitis, bronchial asthma, and suspended particulate.

Follow-up Studies of Respiratory Diseases

A prospective study on chronic airway disease (CAD) was performed among residents of Cracow with the aims of determining prevalence rates in an adult urban population in Poland and evaluating the influence of various sociodemographic and environmental characteristics (12–14). After a cross-sectional survey of the sampled population in 1968, two follow-up surveys were carried out 5 and 13 years later. The concentrations of particulate matter (PM20) and SO_2 were measured in 15 locations in the city. The sulfur transformation rate (STR), i.e., proportion of sulfate sulfur in total sulfur, was also measured and used as an indicator of acid aerosols in ambient air.

For analysis of the relationship between air pollution and respiratory symptoms as well as ventilatory function, two kinds of classification schemes of air pollutants in the city were used. In the first approach, the city was divided into two areas based on PM20 and SO_2 levels (Table 3). In the second approach the city was divided into three areas: Area A: eastern part of the city—high STR (40%), low PM20 and SO_2 ; Area B: western part of the city—intermediate levels of STR (15%), PM20, and SO_2 ; Area C: central part of the city—low STR (10%), high PM20 and SO_2 (Table 4).

The prevalence of chronic respiratory conditions was much higher among men than women (Table 5). A significantly higher prevalence of CAD was observed in areas of residence where the levels of PM20 and SO_2 were higher, as well as a greater risk of chronic respiratory symptoms being persistent (chronic bronchitis lasting at least 5 years) and of exacerbations of respiratory symptoms. The effects were slightly more evident among women. However, chronic bronchitis symptoms were most strongly related to smoking habits. Age and air pollution

showed definite detrimental effects only if combined with occupational exposure or smoking (Tables 6,7). Furthermore, air pollution increased the risk of obstructive airway disease if combined with exposure to thermal stress (variable temperature) in the occupational setting (Table 8).

The FEV₁ decline rate was not statistically related to PM20 or SO_2 . However, it was found that the FEV₁ decline rate in the 13-year followup was significantly faster by 12 ml per year in area A, with presumably the highest level of acid aerosols. This effect was similar in smokers and non-smokers, and was not modified by the reported occupational exposures (Table 9). The Cracow follow-up study showed that the presumed chronic effect on lung function of higher sulfate content and STR in urban air was strong and comparable with the detrimental consequences of smoking.

Another follow-up study was carried out by Polonska et al. (15) in one of the urban districts (Zabrze) in Upper Silesia. The sample covered about 2000 men and women 20 to 64 years of age, observed over 6 years. Respiratory symptoms and spirometric results were recorded together with routinely collected data on air pollution. There was a 3-fold increase in prevalence of chronic bronchitis symptoms in younger men (10–29.4%) during the follow-up period and a 2-fold increase in women (4.3–9.7%). The authors postulate that this increase is related both to smoking and air pollution. In older men there was a smaller increase in the prevalence rate of chronic bronchitis (22.2–43.1%) and this—in the opinion of the authors—could be caused by smoking, occupational factors, and air pollution. The conclusions of the authors pertinent to effects of the environment were based on insufficient environmental data, except for smoking.

Respiratory Disorders in Children

Brezina et al. (16) from Czechoslovakia published some results from a pilot study on 103 children living in an area with substantially polluted air and 103 children from a

Table 3. Average daily air pollution concentrations in Cracow, based on data from a 5-year survey.

Pollution source	Highly polluted area	Less polluted area
Respirable dust	180 $\mu\text{g}/\text{m}^3$	109 $\mu\text{g}/\text{m}^3$
Sulfur dioxide	114 $\mu\text{g}/\text{m}^3$	53 $\mu\text{g}/\text{m}^3$

From Department of Epidemiology and Preventive Medicine, University Medical School in Cracow.

Table 4. Mean daily concentrations of dust and SO_2 in various areas in Cracow, 1976 to 1986.

Area	Particulate matter	SO_2	STR, %
Area A (Nowa Huta)	72	79	43.8–50.7
Area B (rest except old town)	82	85	15.4–20.4
Area C (old town)	110	94	8.7–14.7

From Department of Epidemiology and Preventive Medicine, University Medical School in Cracow.

Table 5. Prevalence of chronic respiratory diseases among adult inhabitants of Cracow.

Diagnosis	Males, %	Females, %
1. Chronic bronchitis	15.6 (8.7)	5.0 (2.5)
2. Asthma	7.8 (3.7)	4.9 (2.4)
3. Obstructive syndrome FEV ₁ % < 60%	6.9 (5.6)	3.4 (1.2)
4. Chronic bronchitis and /or asthma	18.5 (11.0)	8.2 (4.7)
5. Obstructive syndrome (CB-, A-)	2.3 (1.3)	
Total (4 + 5)	20.8 (12.3)	10.8 (5.5)

*Numbers in parentheses indicate symptoms lasting throughout 5 years of followup. From Department of Epidemiology and Preventive Medicine, University Medical School in Cracow.

Table 6. Risk factors for chronic bronchitis estimated from logistic regression.

Risk factor	Males	Females
Air pollution	1.3 NS	0.7 NS
Age (10 years)	1.8	1.5
Smoking	15.4	9.6
Chemicals in HPA	6.5	—
Chemicals in LPA	1.6	—
Humidity in HPA	—	9.4
Humidity in LPA	—	2.1

Abbreviations: HPA, high polluted area; LPA, low polluted area; NS, not significant. From Department of Epidemiology and Preventive Medicine, University Medical School in Cracow.

Table 7. Risk factors in the occurrence or exacerbation of chronic bronchitis or estimated from multiple logistic model Cracow Study.

Risk factor	Males	Females
Air pollution	2.3	0.53 NS
Age (10 years)	2.1	1.1 NS
Smoking	5.0	0.9 NS
Occupational dust exposure	—	3.5
Coal vs gas cooker	—	2.2

From Department of Epidemiology and Preventive Medicine, University Medical School in Cracow.

Table 8. Risk factors for obstructive syndrome estimated from logistic regression

Risk factor	Males	Females
Air pollution	0.6 NS	0.6 NS
Age (10 years)	2.8	2.5
Smoking	4.3	2.3
Education	2.0	—
Variable temperature in HLP	9.4	—
Variable temperature in LPA	1.1 NS	—
Variable temperature only	—	2.4
Chemicals only	—	0.4 NS

Abbreviations: HPA, high polluted area; LPA, low polluted area; NS, not significant. From Department of Epidemiology and Preventive Medicine, University Medical School in Cracow.

Table 9. Effect of residence in areas with various levels of air pollution on FEV₁ decline rate between 1968 and 1981, ml/year, estimated in linear regression models.

Factor	Males (n=584)		Females (n=830)	
	Coefficient	SE	Coefficient	SE
Area A (vs area C)	11.7**	3.7	11.8**	2.4
Area B (vs area C)	11.9**	4.0	3.9 [#]	2.4
Mean level of FEV ₁ , dcl	-1.1**	0.2	-0.6**	0.2
Height, cm	1.6**	0.3	0.7*	0.3
Continuous smoking, CCC				
< 15 cigarettes/day	14.0**	5.3	6.1 ⁺	3.7
> 15 cigarettes/day	8.4*	3.8	8.7**	3.3
Ex-smoking (CCE + CEE)	14.6**	4.5	0.8 [#]	4.2
Constant	-190.2		39.1	
r ²	10.5		4.8	

SE, standard error of the mean; significance of the regression coefficients: *0.05 $p < 0.10$; *0.01 $p < 0.05$; ** $p < 0.01$;

[#]terms not significant ($p > 0.10$) and included in the regression model. From Jedrychowski et al. (14).

control area. Children from the polluted area had significantly worse lung function. The respiratory function in 721 school-children was examined by Bistraninová and Kotěšova (17). The authors found a seasonal variation in respiratory function values. The lowest values were observed in March, and it was assumed that this was due to the high degree of pollution in the preceding winter period.

An epidemiologic investigation of children from Cracow and Limanowa was carried out by Rudnik et al. (18). The authors stated that children without respiratory symptoms were more frequent in Limanowa (rural region) than in the urban area (Cracow).

About 7600 children 8 to 14 years of age were randomly chosen from areas in Upper Silesia with severe pollution (SO_2 150 $\mu\text{g}/\text{m}^3$ and dust fallout 447 t/km^2); with moderate air pollution (SO_2 104 $\mu\text{g}/\text{m}^3$ and dust fallout 250 t/km^2), and mild air pollution (SO_2 51 $\mu\text{g}/\text{m}^3$ and dust fallout 148 t/km^2) (19). The prevalence of symptoms of chronic and recurrent bronchitis, and bronchial asthma was recorded. A positive correlation was found between the occurrence of respiratory symptoms and the level of air pollution. The prevalence of chronic bronchitis in the most polluted area was 2.5%, in intermediate areas 2.0%, and in the lowest polluted area 0.6%; and of recurrent acute bronchitis 13.2, 10.3, and 4.6%, respectively. Bronchial asthma was also more prevalent in the area with highest air pollution (4.9%) when compared with intermediate level (3.8%) and the lowest level or air pollution (1.2%).

Another study compared the prevalence of respiratory disorders in 9- to 10-year-old children in three areas with differing air pollution levels in Upper Silesia (20). In the area with the lowest levels (Zawiercie)

the prevalence of acute diseases of the upper respiratory tract was much lower (17.3%) than in the towns with higher pollution levels (Chorzow, Olkusz), where the rates were 55.6 and 66.0%, respectively. There was no correlation between the degree of air pollution and results of spirometric tests. The annual mean SO_2 concentration in the most heavily polluted town (Chorzow) was 174 $\mu\text{g}/\text{m}^3$, in the less polluted 11 to 96 $\mu\text{g}/\text{m}^3$ (Olkusz), while in the control area it was only 32 $\mu\text{g}/\text{m}^3$. The effect of air pollution and socioeconomic conditions on incidence of chronic and recurrent respiratory infections among school children was studied also in Zabrze and Zdieszowice (high-polluted area) and compared with those in rural areas (21). Children from highly polluted regions had higher rates of respiratory infections, mainly of the upper respiratory tract. Socioeconomic factors appeared to also have some impact on the infection rates. Children from well situated families had lower rates. There were higher rates of respiratory infections in boys than in girls.

A large cross-sectional survey based on medical records covering 560,000 children and adolescents from Upper Silesia was carried out in the period 1977 to 1978 by Rzepka et al. (22). In the area with high pollution the prevalence rates of respiratory disease were three to four times higher than in the area with lower air pollution levels.

In 1980 Saric and co-workers (23) published a study on the effects of urban air pollution on the health of school-age children. For a 6-month winter period FEV values of a group of second graders living in an area with relatively high sulfur dioxide and smoke levels were compared with those of a group of children in a clean-air area. The incidence of acute respiratory diseases in the children and their families was also studied. Indoor and outdoor measurements of sulfur dioxide and smoke were conducted, as well as measurements of SPM and sulfate.

A difference between the compared groups of children and members of their families, regarding both ventilatory volumes and the incidence of acute respiratory diseases, was observed to the disadvantage of those from the polluted area. The results also suggested that at annual average exposure of 70 to 80 $\mu\text{g}/\text{m}^3$ SO_2 , 60 to 80 $\mu\text{g}/\text{m}^3$ smoke, and 130 to 200 $\mu\text{g}/\text{m}^3$ SPM, with frequent higher daily exposures during the heating season, certain effects can be expected, both on the function of the respiratory system and on the occurrence of acute respiratory diseases. If the differences

in expiratory volumes were, in fact, due to the effect of air pollution, they may have been caused either by different exposure levels over a long period or by exposure at the day of measurements. A combined effect is also possible. The question also remains whether the incidence of respiratory diseases was more associated with relatively high annual means or with intermittent high concentrations of atmospheric pollutants.

An investigation on health effects of air pollution was performed by Raileanu et al. (24) in infants from some areas in Moldavia. A correlation was observed between pollution levels and disease rates. The frequency of upper respiratory tract diseases was higher during periods of increased air pollution. Air pollution was also related to bronchopneumonia, ophthalmologic, and allergic diseases. X-ray examinations showed pulmonary fibrosis and emphysema in exposed children.

In a study carried out in Jajce in the Republic of Bosnia and Herzegovina by Ribic and Ribic (25), the incidence of respiratory diseases was monitored over 4 years (1984–1987). The urban population was compared with the population living around the town. A higher incidence of acute respiratory diseases was indicated in preschool children from the urban area than in children from the rural area. A difference—although slighter—in the same direction was also noticed in school children. No difference was found in adults. The authors stated that the findings could partly be attributed to higher concentrations of SiO_2 in air of the town. The source of SiO_2 was a factory for production of ferrosilicium which was located close to the town. Concentrations of SO_2 and chlorine, although not high in the urban air, also have to be considered.

The effect of air pollution on lung function and the rate of nonspecific respiratory diseases was studied in children in the city of Banjaluka, Republic of Bosnia and Herzegovina (26). Children from the area with highest air pollution levels and from rural areas were compared. A statistically significant higher rate of respiratory infections (in upper and lower parts of the respiratory system) was observed in male children living in the polluted city area. FEF_{25} , FEV_{50} , and FEF_{25-75} were also significantly lower in children living in the polluted area. Smoking habits of mothers, use of gas cookers, and central heating were more frequent in the families from the city area than in families in the control area. In the author's opinion, the increased rate of

acute respiratory infections and alterations in pulmonary function in the boys of the city could be related to both outdoor and indoor air pollution. Male school children spent much more time outdoors than female children.

Rudnai and co-workers (27) carried out two epidemiologic studies in Hungary on the association between air pollution in the town of Ajka and respiratory morbidity of children. The most important pollutants were SO_2 , black smoke, dust, and PAHs. The control population was chosen from a town, Pápa, which is about 30 km from Ajka. One study included children 1 to 2 years of age who attended nurseries. Annual morbidity rates from different diseases were 57.6 % higher in Ajka than in Pápa.

Dávid et al. (28) evaluated the correlation between air pollution and acute respiratory morbidity of children in the town of Dorog in Hungary. Dorog has been highly polluted with SO_2 and dust due to a coal mine, a coal-fired power plant, and coke production. Air quality was measured at four stations in the town. Respiratory diseases were registered monthly in four age groups (0, 1–2, 3–5, 6–14 years) over 1 year. Correlation analysis showed a strong association between monthly morbidity rate of all respiratory diseases and mean monthly level of SO_2 pollution ($r = 0.83$).

Lung Cancer

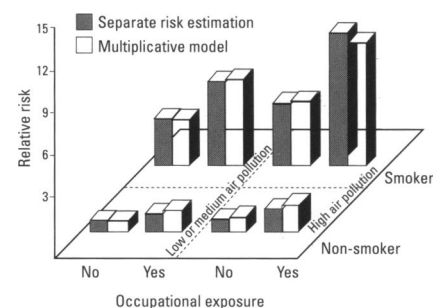
Significantly higher mortality rates from lung cancer have been found in inhabitants of Cracow in comparison to national data (29). There was a differential distribution of cancer deaths across the city, with the highest SMR in the city center having highest TSP and SO_2 concentrations. Since smoking habits in different sections of the city were about the same, the authors postulated that the excess in number of deaths from lung cancer in the city center probably was caused by air pollution.

In a case-control study of lung cancer deaths occurring over a 6-year period (1980–1985) in Cracow, it was found that air pollution may increase lung cancer risk, acting multiplicatively with known factors such as smoking and industrial exposure (30). Information on occupation, smoking habits, and residence was collected from next of kin. Classification of exposure to community air pollution was based on measured levels of total suspended particulate matter and sulfur dioxide. Lung cancer risk depended strongly on total cigarette consumption, on age at starting to smoke, and on time since stopping smoking.

Relative risk estimates for occupational exposure in iron and steel foundries and in other industries were significantly increased in males. The relative risk in men exposed to the highest air pollution level was 1.48 (95% confidence interval 1.08–2.01), while in women the increase was not significant (Tables 10,11). The joint action of smoking, occupational exposure, and air pollution was found to closely fit a multiplicative model (Figure 1).

Conclusions and Recommendations

Epidemiologic studies support the hypothesis that air pollutants in the place of residence or at work may have a detrimental effect on the respiratory tract and other important body systems. Their effect depends on the nature of exposure, its concentration and duration (doses), and the susceptibility of the population under exposure. Most of the studies were not able to demonstrate a dose-response relationship and this was probably due to the fact that very poor information on air pollutant exposure was used. Frequently, emission data were taken as a proxy measure for air pollutant concentrations. A second major weakness of many studies resulted from disregarding other variables that may confound the influence of air pollution. A third weakness was that many studies were



Air pollution	Occupational exposure	
	No, Est./Model	Yes, Est./Model
Low or medium		
Nonsmoker	1.0/1.0	1.76/1.86
Smoker	4.80/4.76	8.50/8.85
High		
Nonsmoker	1.14/1.42	2.37/2.64
Smoker	6.68/6.76	13.6/12.6

Figure 1. Multiplicative effect of smoking, occupational exposure, and air pollution on risk of lung cancer.

Table 10. Odds ratio estimates for lung cancer deaths in males, adjusted to age, based on multiple logistic model, Cracow, Poland, 1980 to 1985.

Variable	Cases, <i>n</i> =901	Controls, <i>n</i> =875	RR	(95% CI)
Smoking				
Never smokers	49	219	1.00	
Dose ^a				
1–19	131	180	3.48	(2.33, 5.19)
20–29	426	295	6.16	(4.25, 8.19)
>29	278	143	7.69	(5.15, 11.47)
Unknown	17	38	2.41	(1.24, 4.68)
Age at start of smoking				
<17	135	66	1.66	(1.19, 2.32)
17–18	239	146	1.30	(1.00, 1.68)
Years since stopped smoking				
>10	73	138	0.40	(0.29, 0.56)
>5–10	64	58	0.66	(0.45, 0.98)
Occupational exposure				
No exposure	561	677	1.00	
In foundries	106	72	1.56	(1.10, 2.21)
In other industries	234	126	1.96	(1.51, 2.55)
Air pollution				
Low	650	631	1.00	
Medium	129	140	1.00	(0.75, 1.33)
High	122	104	1.46	(1.06, 1.99)

Abbreviations: RR, relative risk; CI, confidence interval. ^aAverage number of cigarettes smoked daily. From Jedrychowski et al. (30).

Table 11. Odds ratio estimates for lung cancer deaths of females, adjusted to age based on multiple logistic model, Cracow, Poland, 1980 to 1985.

Variable	Cases, <i>n</i> =198	Controls, <i>n</i> =189	RR	(95% CI)
Smoking				
Never smokers	78	166	1.00	
Dose ^a				
1–19	37	10	6.37	(2.66, 15.24)
20–29	52	16	2.38	(1.17, 6.86)
>29	28	4	7.37	(2.20, 24.69)
unknown	3	2	2.94	(0.47, 18.59)
Age at start of smoking				
<23	63	11	1.77	(0.68, 4.60)
Years since stopped smoking				
>5	13	8	0.51	(0.17, 1.50)
Occupational exposure				
Nonmanual worker	166	183	1.00	
Manual worker	32	15	2.02	(0.94, 4.35)
Air pollution				
Low	124	134	1.00	
Medium to high	74	64	1.17	(0.70, 1.96)

Abbreviations: RR, relative risk; CI, confidence interval. ^aAverage number of cigarettes smoked daily. From Jedrychowski et al. (30).

not powerful enough to uncover the sometimes small environment-related health effects at the population level. Since the air pollution exposure does not occur exclusively at the place of residence, future studies should consider total exposure assessment, which could be useful also for risk management programs.

In future studies more attention should be given to the measurement of environmental pollution in such a way that one could get information on doses of specific

pollutants and not only emissions or concentrations. This generally constitutes the most difficult and expensive part of environmental epidemiology studies. However, if these difficulties are not resolved, there would be no scientific justification to carry out such studies. Establishing national or regional networks of monitoring stations would facilitate epidemiologic studies on health effects of the environment. Because this is an extremely expensive endeavor, one has to consider some international

collaborative efforts not only between post-Communist countries themselves but also involving other countries.

An effort should be made to employ in a better way the routinely collected data on health outcomes, such as hospital morbidity or visits to outpatient clinics, and to link them with environmental exposure data. Registries of birth and death events, as well as registries of congenital malformations, should be established in each country.

To assess as early as possible preclinical stages of health impairment due to environmental exposure, new techniques for using biological markers of exposure or tissue damage must be introduced.

Each country in the region should concentrate on its specific environmental problems and their health consequences. However, epidemiologic studies to be carried out in the future also should be coordinated. It is obvious that health effects due to a given exposure factor can be demonstrated more easily and more effectively in environmental settings in which high exposures occur. Therefore, studies should be carried out in such areas and adequate amounts of money made available through national and international agencies.

The scientific standard of the papers that have been reviewed was often poor. This means that training in the field of environmental epidemiology is of great importance. Courses at the national and international levels should be introduced for undergraduate as well as for postgraduate students. It must be stressed that the teaching staff in all kinds of courses should be recruited from among the top specialists in the field, which often means invitation of scientists from abroad. In these circumstances there may be a communication problem due to language barriers between teachers and participants. Therefore, it is reasonable to accept the principle that the courses, especially at the postgraduate level, should be held in English and the participants in the courses should be recruited properly. This would greatly facilitate the communication, supervision, and evaluation of the courses by international scientific bodies. Certainly, this is not an easy or quick process; however, even at this moment the first few steps in this direction should be taken. International bodies could be created to cooperate in programming and to exchange experience in training.

The results of the epidemiologic studies in our region are mostly presented in local scientific journals, which are usually

lished in the national languages. The English summary often does not help very much in grasping even the basic messages coming from the studies. That is due,

partly, to the vague construction of abstracts. Some of these journals are not indexed; therefore, papers cannot be located by computer search systems. It is

recommended, therefore, that new journals on environmental health in the region should be published in English, possibly with an international editorial board.

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